의학박사 학위논문

돼지심부전모델을 이용한 동정맥 체외막형 산소화장치에서 대동맥내 풍선장치의 혈역학적효과

Hemodynamic Impacts of Intra-Aortic Balloon Pump on Veno-Arterial Extracorporeal Membrane Oxygenator in Porcine Heart Failure Model

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Thoracic and Cardiovascular Surgery, Medicine

Seoul National University Graduate School

Jun Sung Kim

Abstract

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Background: Intra-aortic balloon pump (IABP) may reduce the afterload on the left ventricle as a result of pulmonary congestion from veno-arterial extracorporeal membrane oxygenation (ECMO) support. This animal experiment aims to elucidate the hemodynamic impacts of IABP on ECMO with porcine heart failure model.

Methods: The femoral artery and vein of 69~85kg pigs were cannulated for ECMO support by percutaneous or open technique. Left lateral thoracotomy via 4th intercostal level was performed for invasive catheterization and cardiac intervention. We checked various hemodynamic parameters, including left atrial pressure, coronary blood flow on the left

anterior descending coronary artery, and left subclavian artery blood flow using a Doppler. The ECMO was applied for one hour and IABP was added on the counterpart femoral artery for another one hour. In the heart failure model, we induced heart failure by pulmonary artery banding to maintain the mean arterial blood pressure below 60mmHg prior to starting ECMO support. We checked same parameters before and after the IABP support (n=4).

Results: In the normal heart model, IABP had no impact on hemodynamic change, such as mean blood pressure (118.3±25.2 ECMO only vs. 86.8±17.1mmHg ECMO+IABP, p=0.068), left atrial pressure (9.3±7.4 vs. 3.3±2.6mmHg, p=0.068), coronary blood flow (28.4±5.4 vs 23.6±7.7mL/min, p=0.068), or left subclavian artery flow (161.9±55.8 vs. 123.3±45.9 mL/min, p=0.465). In the heart failure model, IABP showed no significant hemodynamic advantage over ECMO only support; the mean blood pressure (93.8±20.5 vs. 89.3±19.6mmHg, p=0.716), left atrial pressure (7.5±3.3 vs. 5.5±2.5mmHg, p=0.144), coronary blood flow (26.4±9.4 vs. 21.7±3.4mL/min, p=0.197), and left subclavian artery flow (125.6±52.4 vs. 122.3±53.4mL/min, p=1.000).

Conclusion: IABP seems to not affect hemodynamic change on veno-arterial ECMO support even in the heart failure model. The effect of IABP appears to be minimal during maximal ECMO support.

Keywords: Mechanical circulatory support, Heart failure, ECMO, IABP, Animal experiment, Heart failure model

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INTRODUCTION

Mechanical circulatory support (MCS) systems, such as intra-aortic balloon pump (IABP) and venoarterial extracorporeal membrane oxygenation (ECMO), are powerful treatment tools manage patients who experienced cardiogenic shock and are refractory to maximal inotropic therapy. Proper management of these patients requires an aggressive application of MCS. Theoretically, IABP can help the failing heart with ECMO support to relieve afterload, reduce myocardial oxygen demand, and increase coronary perfusion (1-6). A major concern in the management of a failing heart with ECMO is that it requires relief of ventricular end-diastolic pressure and reduction in the afterload on the left heart. To avoid invasive surgical procedures, such as left ventricular vent catheter insertion, IABP is usually attempted prior to surgical intervention. Moreover, cerebral blood flow and coronary blood blow are augmented by the help of IABP, and we expect the improvement of brain and coronary perfusion with IABP on venoarterial ECMO support (1). However, clinical benefit of IABP with respect to survival or morbidity has not been fully elucidated in cardiogenic shock patients with ECMO (7-10).

Currently, the efficacy of IABP on ECMO in failing hearts remains contended. Due to the critical status of patients in clinical situation, the hemodynamic impact of IABP on ECMO has shown to be advantageous or disadvantageous and there is no large, prospective, randomized controlled study so far. In their absence, we would like to elucidate the hemodynamic impacts of IABP on venoarterial ECMO by the means of

animal heart failure experiment which can control and moderate other matters on this critical ill-status as possible.

MATERIALS AND METHODS

The animal experiment was approved by the Animal Research Ethical Committee at Seoul National University Bundanag Hospital (BA1505-176/021-01). This research was supported by a grant of the Korea health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare Republic of Korea (grant number : HI14C0746).

Study Design

We used eight domestic laboratory Swine (mean 76.2 (66.0~84.5) kg, Cronex, Chungcheongbuk-do, Korea) for the experiment. We divided them into two groups: the normal heart group (n=4) and the heart-failure group (n=4). We attempted to determine the difference between the two groups and whether disease pathology may affect the outcome. Before starting the main experiment, we performed a pilot study to determine the feasibility of the experiment with four pigs. We adjusted the protocols for the study in detail.

The primary end point of this study was to evaluate the change in the left atrial pressure (LAP), left anterior descending coronary artery (LAD) flow, which represents global coronary blood flow, and left subclavian artery (LSCA) flow, which represents cerebral blood flow before and after IABP support on venoarterial ECMO in both groups. The secondary end point was to verify the change in the mean blood pressure (mBP), central

venous pressure (CVP) for usual hemodynamic parameter, and blood sample (hemoglobin, arterial blood gas analysis, lactate) in both groups.

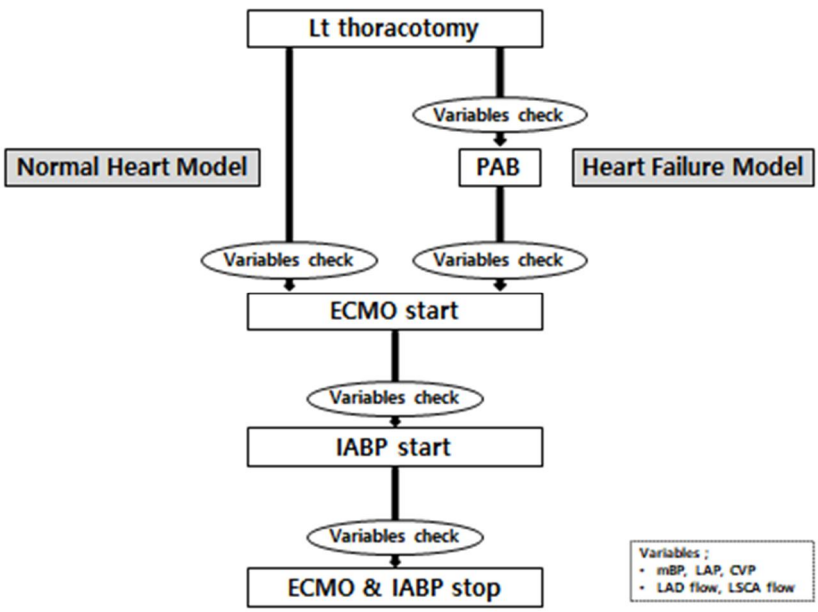

Figure 1. Animal experiment flowsheet

Anesthesia and surgery

All swine pigs were raised with commercialized solid feed in each cage; they were fasted overnight prior to surgery. Premedication consisted of subcutaneous injection of atropine 0.05mg/kg and intramuscular injection of xylazine 3mg/kg (Rompun® , Bayer

Korea, Ansan-si, Korea) and zoletil 5mg/kg (Zoletil®50, Virbac S.A, Carros, France), administered in the animal cage before the pigs were transferred to the laboratory operation room next door. After induction of anesthesia, pigs were intubated via mouth with 7.5mm endotracheal tube and connected to mechanical ventilator (Datex-Ohmeda, GE, USA). Anesthesia was maintained with sevoflurane 2.2% (Sevofran, Hana Pharm. Co. Ltd, Seoul, Korea) and supplemented by oxygen 2L/min with inspired oxygen f0r0action of 40%. Other ventilator parameters were adjusted according to arterial blood gas analysis to achieve normoventilation. Muscle paralysis was maintained by vecuronium bromide 0.1mg/kg (Vecaron, Reyon Pahrm.Co.Ltd, Chungcheongbuk-do, Korea).

After the induction of anesthesia, each animal down with supine position with semi right decubitus tilting position for left thoracotomy and four legs were fixed to the table with rope. Skin was prepared with 1% bethadine solution. Draping was done to expose both inguinal area and left thoracotomy was performed. Arterial BP monitoring catheter was inserted into the left or right femoral artery via the sono-guided Seldinger technique, and left lateral thoracotomy was performed via the 4th intercostal space. After pericardiotomy, we inserted a CVP catheter into the superior vena cava and LAP catheter into the left atrium. Then, LAD and LSCA were freed by surgical dissection for flow measurement with sono-doppler machines; 4.0mm coronary probe of Transit time flowmeter (Medistim MiraQ Systems, Medistim ASA, Oslo, Norway) for LAD flow measurement and linear vascular probe of Philips iE33 ultrasound system (Philips Medical Systems, Bothel, WA, USA) for LSCA flow, and we gained a ‘basal data’ (#1)

for primary and secondary end point parameters. Each measurement was checked by three consecutive measures, and we took the mean value to minimize measurement bias.

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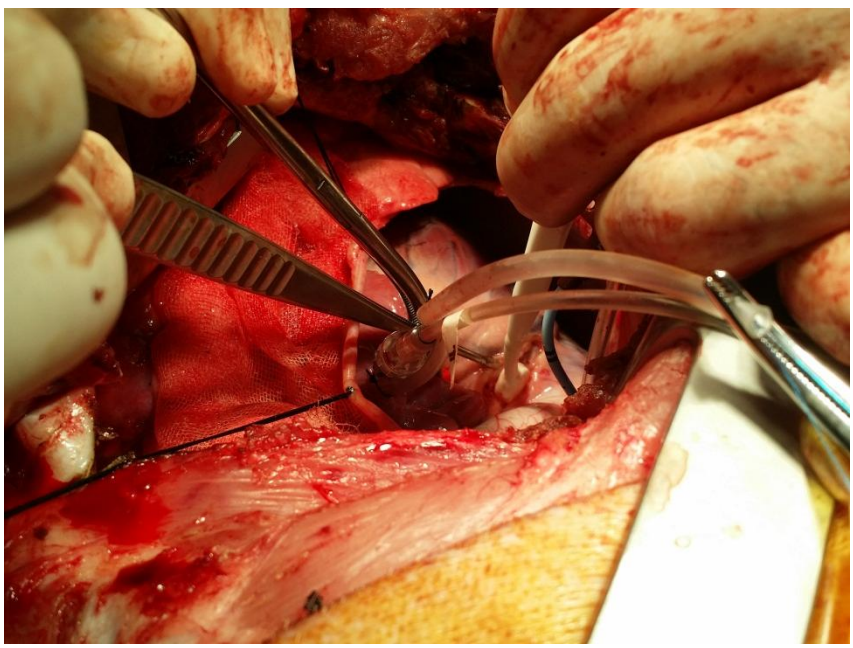
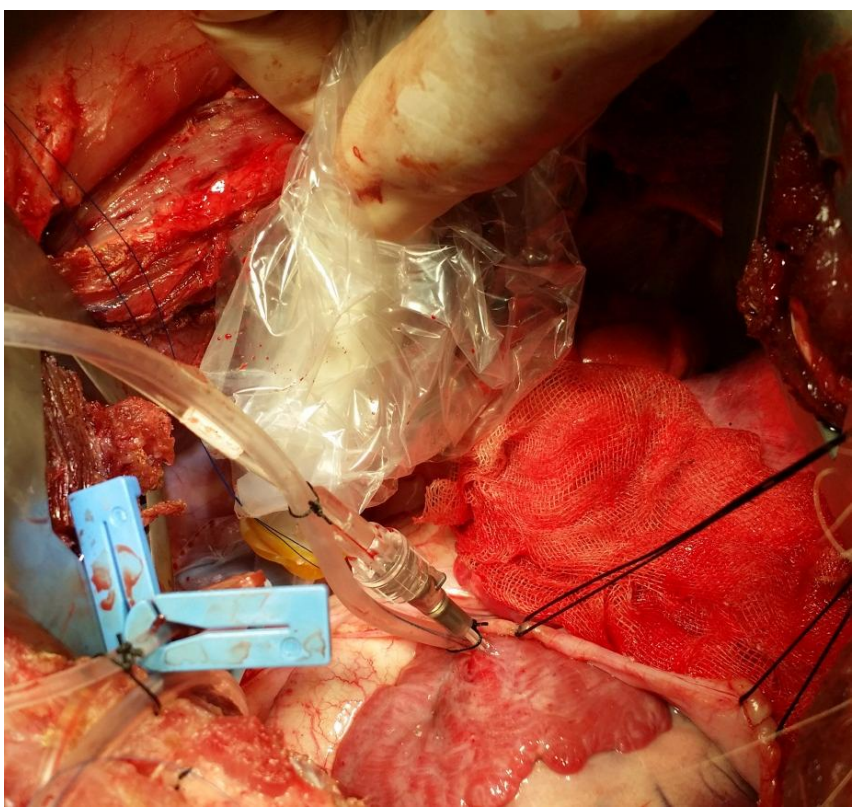


B)

Figure 2. LAD blood flow check with TTFM.

In the heart failure group, the shock status was induced by pulmonary artery banding (PAB) with an adjustable snaring-down technique that could reduce mBP under 60mmHg; we checked the LAD, LSCA blood flow, and other parameters for 'after PAB (pulmonary artery banding, #2)'. During surgical procedure, effort was made to avoid bleeding through the incorporation of meticulous surgical technique and monopolar electrocautery.

A) 

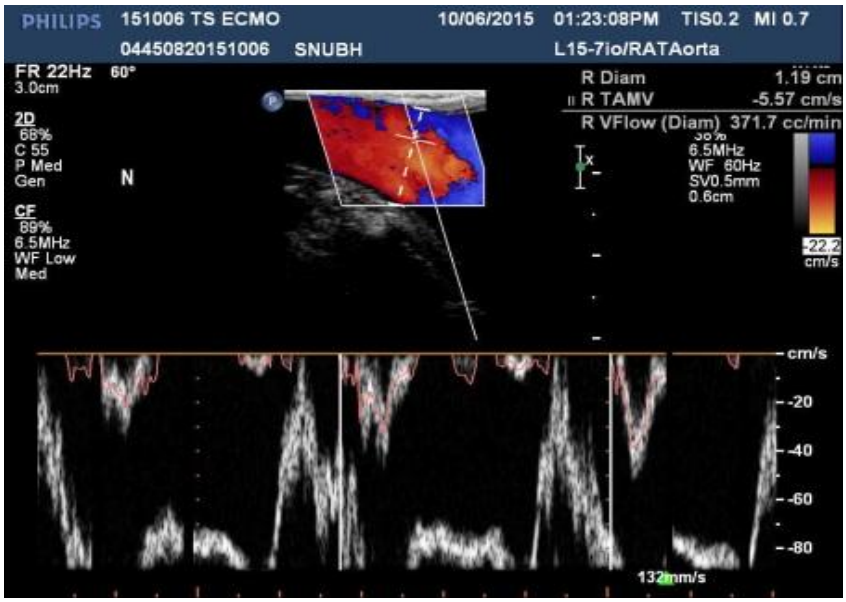
B) 

Figure 3. LSCA blood flow check with doppler.

Next, in both group, we inserted the venoarterial ECMO cannula with open technique into the contralateral femoral artery (BIO-MEDICUS® Femoral Arterial Cannula 15Fr, Medtronic, MN, USA) and vein (BIO-MEDICUS® Femoral Venous Cannula 17Fr, Medtronic, MN, USA) after heparin intravenous injection (2mg/kg). Activated clotting time was checked every two hours and maintained over 150 seconds with sporadic additional heparin infusion. After conventional priming for ECMO (Permanent Life Support, Maquet, Rastatt, Germany), we connected the cannula to the ECMO circuit, and ran for one hour to maintain stable vital sign signals. During observation, Ringer's acetate solution was infused at a rate of 100mL/hour to replace lost fluids and bleeding to maintain ECMO flow over 2.0L/min. After one hour, we checked the LAD, LSCA flow,

and other parameters again for the 'post-ECMO' (#3) value. Then, we inserted IABP catheter (25mL balloon, 7.5Fr, Maquet, Fairfield, NJ, USA) on left femoral artery through preexisting arterial BP monitoring line. IABP (Datascope System 98, Mahwah, NJ, USA) was maintained with one by one full augmentation per beat. After one hour of observation, we checked both blood flows and other parameters again for 'post-IABP' (#4). Patients were then weaned off IABP and ECMO seperately, and the vital signs were observed for one hour. The last blood sampling of secondary end point parameters was taken. We finally sacrificed the animal using high dose potassium injection by animal experiment guideline.

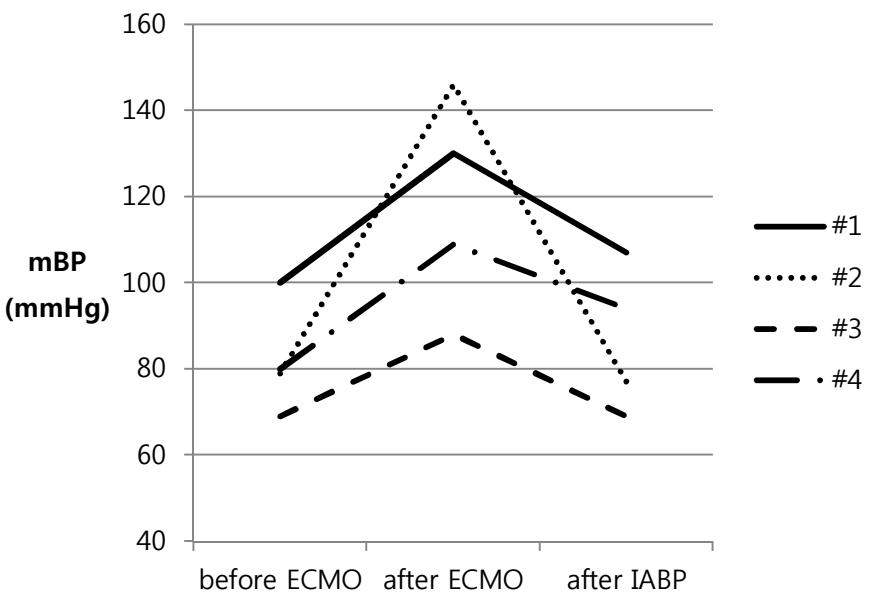
Statistical methods

Data are the mean ± standard deviation. All statistical analyses were performed with statistical software, PASW, version 22 (Chicago, IL, USA). Wilcoxon signed rank test was performed to analyze the change between before and after the intervention. Statistical differences are presented in terms of actual changes in P-value. A level of $P < 0.05$ was considered statistically significant.

RESULTS

1. Normal Heart Model

In normal heart function, LAP showed an increasing tendency after ECMO (6.5±2.6 to 9.3±7.4mmHg), which returned below the basal level after IABP (9.3±7.4 to 3.3±2.6mmHg, p=0.068), without statistical significance. However, LAD flow decreased from 34.8±6.9mL/min to 28.4±5.4mL/min after ECMO application and to 23.6±7.7mL/min after IABP application (p=0.068) without statistical significance. The same tendency of LSCA flow change was shown between ECMO and IABP (basal 213.0±104.6mL/min, after ECMO 161.9±55.8, after IABP 123.3±45.9, p=0.465).



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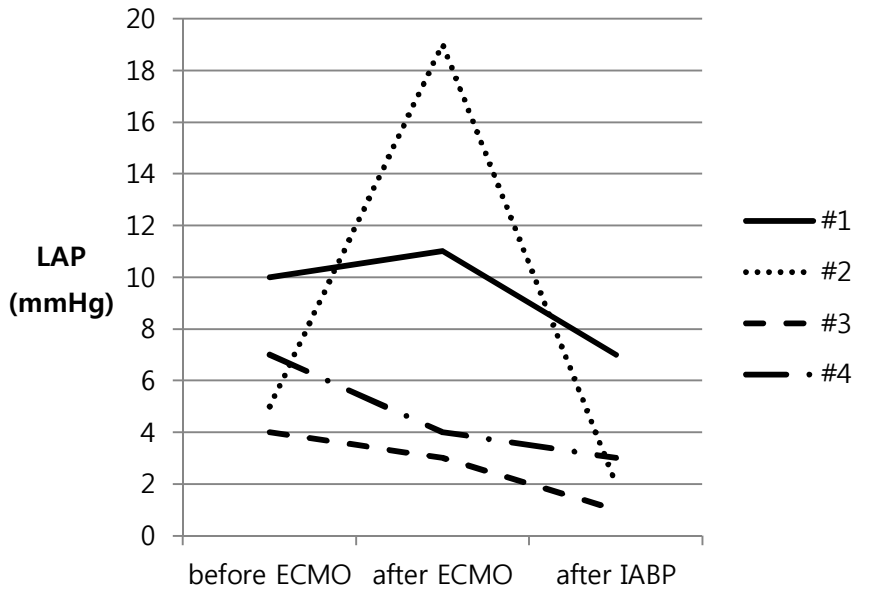
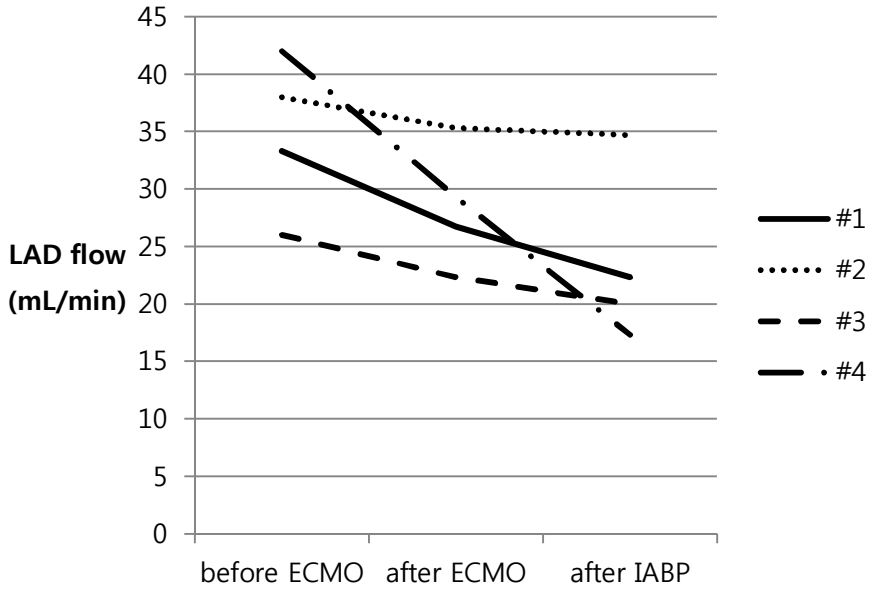


C)

	Before ECMO	After ECMO	After IABP	P-value
mBP (mmHg)	82.0±13.0	118.3±25.2	86.3±17.1	0.068
LAP (mmHg)	6.5±2.6	9.3±7.4	3.3±2.6	0.068
CVP (mmHg)	6.5±7.1	4.8±8.9	3.3±7.9	0.109

Figure 4. Changes of hemodynamic parameters in normal heart model.

Regarding the other hemodynamic parameters, mBP was showing a similar tendency to LAP, with a basal level of 82.0±13.0mmHg, which increased after ECMO to 118.3±25.2, and then decreased to 86.8±17.1 after IABP (between after ECMO and after IABP, p=0.068). CVP decreased from basal 6.5±7.1mmHg, to 4.8±8.9 after ECMO and 3.3±7.9 after IABP (between after ECMO and after IABP, p=0.109) without statistical difference.



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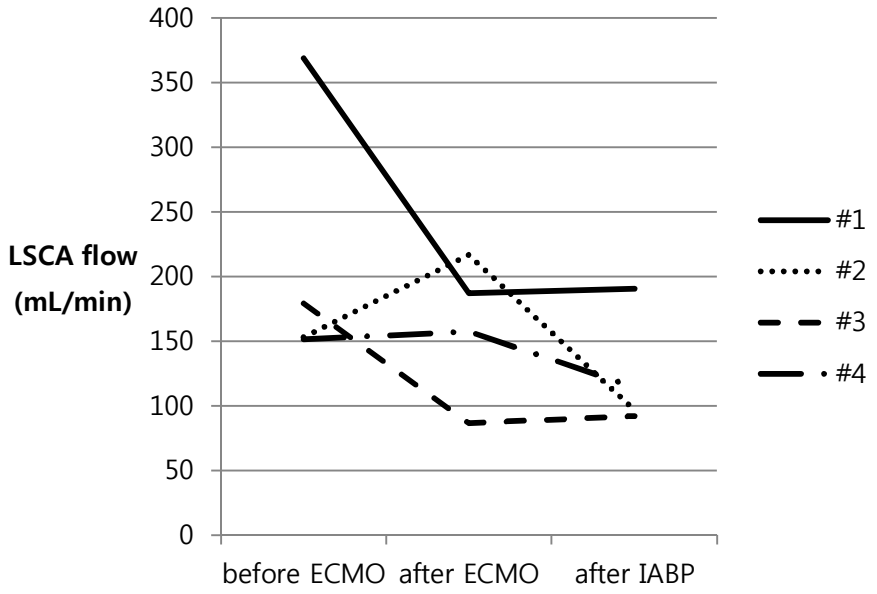


B)

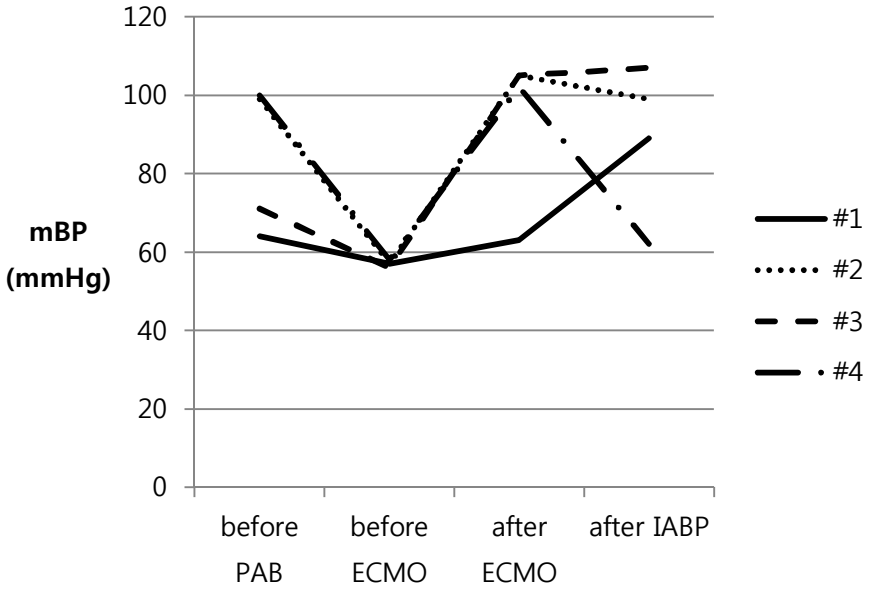
C)

	Before ECMO	After ECMO	After IABP	P-value
LAD flow (mL/min)	34.8±6.9	28.4±5.4	23.6±7.7	0.068
LSCA flow (mL/min)	213.0±104.6	161.9±55.8	123.3±45.9	0.465

Figure 5. Changes of blood flows in normal heart model.

2. Heart Failure Model

After pulmonary artery banding, a shock status of below 60mmHg of mBP was obtained. LAP decreased from 12.3±1.3mmHg basal level to 8.8±1.7 after PAB, to 7.5±3.3 after ECMO, and to 5.5±2.5 after IABP (between after ECMO and after IABP, p=0.144) without significance. The LAD flow also decreased from 38.7±1.8mL/min basal level to 37.4±6.3 after PAB, to 26.4±9.4 after ECMO, and to 21.7±3.4 after IABP (between after ECMO and after IABP, p=0.197) without significance. The LSCA flow showed a similar trend; from a basal level of 166.7±79.3mL/min to to 127.7±59.4 after PAB, to 125.6±52.4 after ECMO, and to 122.3±53.4 after IABP (between after ECMO and after IABP, p=1.000) without significance.



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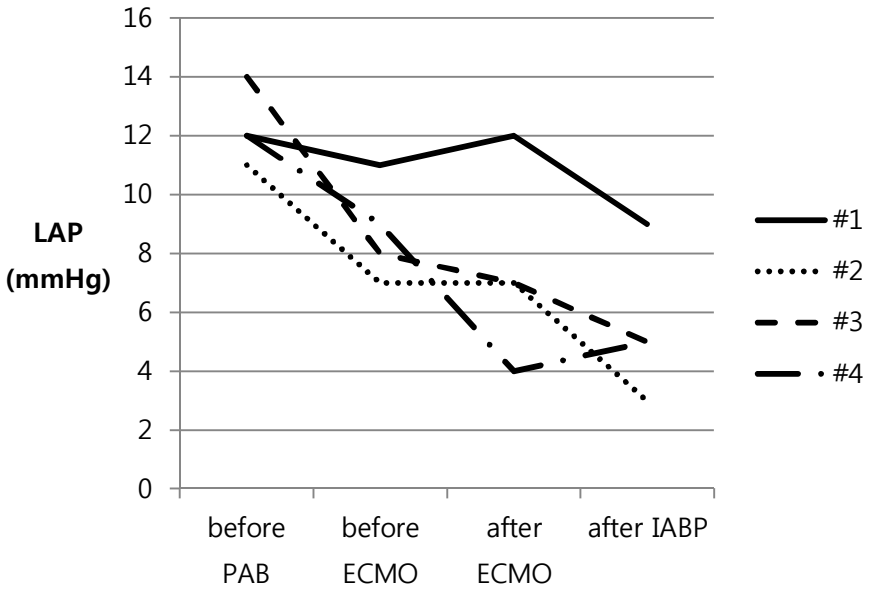


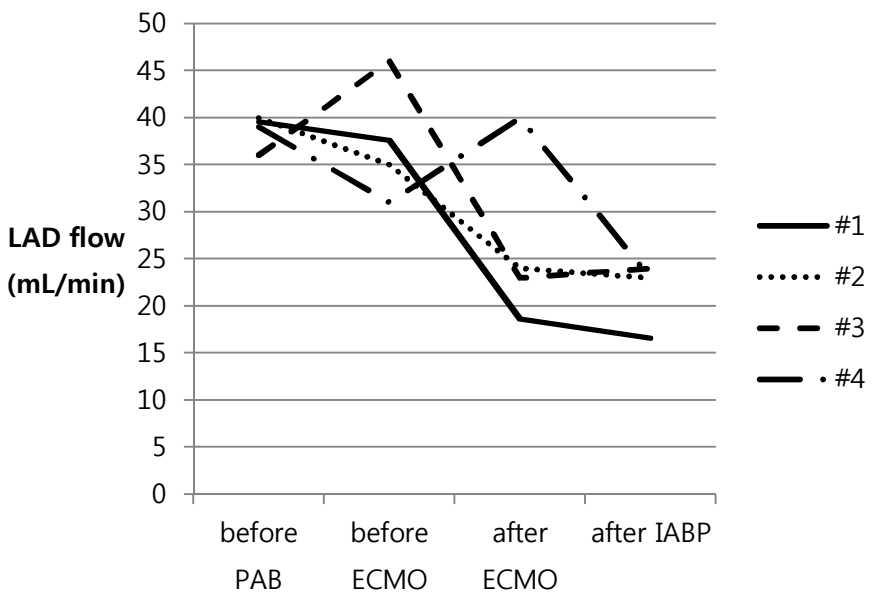
B)

C)

	Before PAB	Before ECMO	After ECMO	After IABP	P-value
mBP (mmHg)	83.5±18.7	57.0±0.8	93.8±20.5	89.3±19.6	0.716
LAP (mmHg)	12.3±1.3	8.8±1.7	7.5±3.3	5.5±2.5	0.144
CVP (mmHg)	7.8±3.0	9.3±3.4	4.3±1.0	3.3±2.1	0.465

Figure 6. Changes of hemodynamic parameters in heart failure model.

Regarding the other hemodynamic parameters, mBP decreased after PAB from 83.5±18.7mmHg to 57.0±0.8. Then, ECMO elevated it up to 93.8±20.5; however IABP did not affect mBP to 89.3±19.6 (p=0.716). CVP increased from 7.8±3.0mmHg to 9.3±3.4 after PAB. Then, ECMO brought CVP down to 4.3±1.0, and IABP also reduced the CVP to 3.3±2.1 (p=0.465) without significance.



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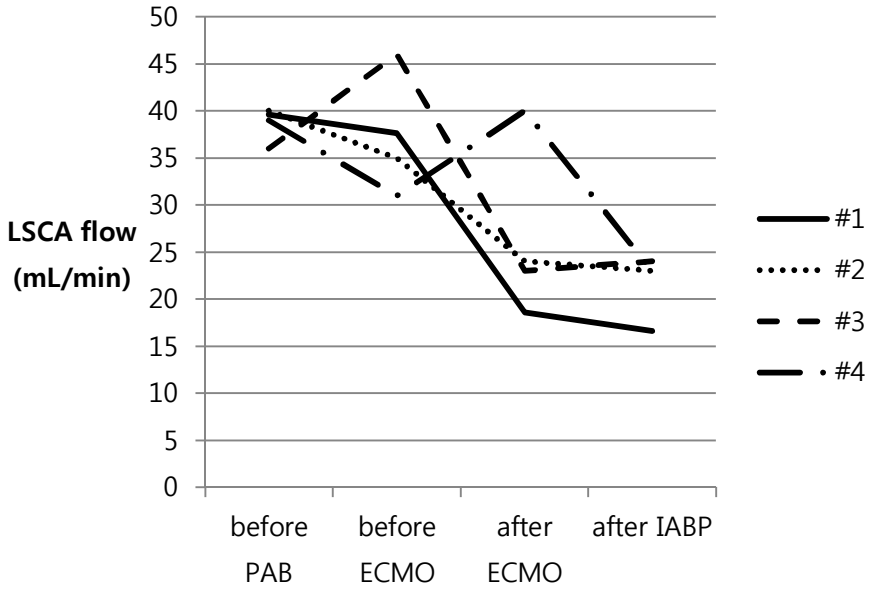

C)

	Before PAB	Before ECMO	After ECMO	After IABP	P-value
LAD flow (mL/min)	38.7±1.8	37.4±6.3	26.4±9.4	21.7±3.4	0.197
LSCA flow (mL/min)	166.7±79.3	127.7±59.4	125.6±52.4	122.3±53.4	1.000

Figure 7. Changes of blood flows in heart failure model.

DISCUSSION

The main finding of this experiment was that IABP does not affect hemodynamic change on veno-arterial ECMO support even in the heart failure model. As mentioned on the results of this study, IABP plus ECMO did not improve any hemodynamic parameters, including coronary blood flow and cerebral blood flow, on both normal and failing hearts.

In our study, we demonstrated that the use of IABP may reduce the LAP in both the normal heart (9.3 to 3.3mmHg) and heart failure models (7.5 to 5.5mmHg) during ECMO run like IABP alone status without statistical significance. Seven animals out of eight showed a slight reduction of LAP after IABP support during ECMO. Compared with IABP alone, the systolic unloading effect appears to be minimized due to the retrograde flow from the femoral artery during ECMO support. In the heart failure model, PAB itself is another LAP lowering maneuver that causes preload reduction for left ventricle.

Moreover, coronary blood flow and cerebral blood flow decreased after IABP in both models during ECMO, unlike IABP alone status. We suggest that major augmented blood flow from distal femoral artery (ECMO flow) is blocked by balloon during diastolic phase during ECMO support. In the IABP alone status, major augmented blood flow is native cardiac output from aortic valve. This different major blood flow source appears to be the cause of coronary and cerebral blood flow reduction during ECMO support. However, there is a contrasting clinical result about the bypass graft flow measurement

during ECMO plus IABP or not. They demonstrated that there was a 17% incremental graft flow of CABG on ECMO plus IABP in only 6 patients.(11)

Our result is in accordance with some previous reports (12, 13). Bělohlávek et al performed a similar experiment using eleven pigs (12). They induced heart failure with ventricular fibrillation and checked for coronary and carotid blood flows before and after IABP support during venoarterial ECMO. They also found that IABP significantly impaired coronary perfusion when compared with ECMO alone. While they compared with the right subclavian artery outflow of ECMO, subclavian approach seemed to be suitable for IABP assistance because perfusion catheter was located proximal to the IABP balloon. This finding supports and helps explain our results. We discarded the ventricular fibrillation method as a heart failure model because regular rhythm was important for the diastolic augmentation effect of IABP.

In clinical practice, many physicians have a big dilemma about the decision to add IABP in patients who would not get better after only veno-arterial ECMO and show no pulsatile self-pulse pressure on arterial line. In such circumstances, most ideal and effective mechanical device for recovery is the left ventricular vent catheter insertion (14). However, this procedure demands an invasive surgical method, causing massive bleeding and hypovolemic shock that can result in ultimate death. In this situation, IABP is the easiest way to support the patients by afterload reduction and diastolic augmentation principles (1, 2, 4). In spite of the limited and conflicting evidence, many centers routinely placed IABP at the initiation of ECMO as an adjunctive therapy. An addition of IABP on veno-arterial ECMO is considered helpful and is used both in

cardiogenic shock status and during successful weaning from ECMO or cardiopulmonary bypass (1, 2, 15).

However, there are reports of meta-analysis study instead of randomized study. Cheng et al reported that there was no survival benefit of concomitant use of IABP with ECMO by systematic meta-analysis with 16 observational study and 1517 patients. They showed that the overall survival with ECMO plus IABP was 35.5%, which was 37.5% for ECMO; it was not a compared with the ECMO alone, which was 37.5% (p=.10) and same results were observed on the sub-group analysis (AMI patients, post cardiotomy patients, prior IABP insertion)(16). Another larger meta-analysis incorporating 22 studies, with a total of 4653 patients, also reported that the use of IABP did not influence mortality in the total cohort, but it was associated with 18.5% lower mortality in AMI patients group (17).

For rescue therapy of those critical patients, we should take into consideration between benefit and risk complication. The concomitant support of IABP and ECMO usually carry more risk of vascular complications, hemolysis and medical financial cost (8, 9, 18, 19).

With our animal study and other meta-analysis reports, we suggest other form of adjunctive therapy for LV recovery or patient survival. Unfortunately, more recent aggressive mechanical supports, like percutaneous LV or LA venting, also showed no survival gain on those patients (20, 21). Ultimately, early recognition of irreversible LV failure and heart replacement therapy, such as implantable left ventricular assist device or heart transplantation might be a promising strategy (14, 20, 22, 23).

In this study, there are some limitations to conclude . First, a small number of experiments is not enough to generalize the outcomes regarding the parameters examined. Our animal research ethical committee recommended a small number of animals for the study. We had to perform this study with restricted numbers of experiment, including four pilot tries. However, similar tendency was observed in each group; acceptable results were obtained after eight animals. Second, we could not make a successful left heart failure model. There is a few of model of left heart failure model such as coronary ligation, tachycardia induced fashion, cardio-toxic agent mediated model. We accepted pulmonary artery banding as a heart failure model because other the left heart failure models are too risky to maintain minimal vital signs or take too much time to induce shock status. Although pulmonary artery banding method is technically a right heart failure model and a left heart preload reduction model, it is very useful to induce shock status and considered safe to maintain minimal vital sign. However, there might be contrary effect to the left heart failure mechanism, which indicates that preload reduction may be different from the over –afterload mechanism with regards to the left heart. LAP in particular is easily affected by preload reduction, and the pulmonary artery banding method would not increase LAP after maximal support of ECMO. Lastly, we observed those parameters only one hour after manipulation, which may have been too short to obtain sufficient effect.

This animal experiment is the first study to elucidate the hemodynamic change in the use of IABP during ECMO support. Despite several limitations, by means of direct

measurement of coronary and cerebral blood flow and LAP, we found that IABP support during ECMO was quite different situation from IABP alone physiology.

CONCLUSION

IABP does not affect hemodynamic change on veno-arterial ECMO support even in heart failure model. During ECMO support, IABP may induce minimal systolic unloading effect and may not increase the coronary and cerebral blood flow. The effect of IABP is seemed to be minimal because major blood flow is retrograde fashion by femoral artery ECMO flow.

REFERENCES

1. Madershahian N, Wippermann J, Liakopoulos O, Wittwer T, Kuhn E, Er F, et al. The acute effect of IABP-induced pulsatility on coronary vascular resistance and graft flow in critical ill patients during ECMO. The Journal of cardiovascular surgery. 2011;52(3):411-8.

2. Buckley MJ, Leinbach RC, Kastor JA, Laird JD, Kantrowitz AR, Madras PN, et al. Hemodynamic evaluation of intra-aortic balloon pumping in man. Circulation. 1970;41(5 Suppl):II130-6.

3. Jung C, Lauten A, Roediger C, Fritzenwanger M, Schumm J, Figulla HR, et al. In vivo evaluation of tissue microflow under combined therapy with extracorporeal life support and intra-aortic balloon counterpulsation. Anaesth Intensive Care. 2009;37(5):833-5.

4. Powell WJ, Jr., Daggett WM, Magro AE, Bianco JA, Buckley MJ, Sanders CA, et al. Effects of intra-aortic balloon counterpulsation on cardiac performance, oxygen consumption, and coronary blood flow in dogs. Circ Res. 1970;26(6):753-64.

5. Lin LY, Liao CW, Wang CH, Chi NH, Yu HY, Chou NK, et al. Effects of Additional Intra-aortic Balloon Counter-Pulsation Therapy to Cardiogenic Shock Patients Supported by Extra-corporeal Membranous Oxygenation. Sci Rep. 2016;6:23838.

6. Leinbach RC, Buckley MJ, Austen WG, Petschek HE, Kantrowitz AR, Sanders CA. Effects of intra-aortic balloon pumping on coronary flow and metabolism in man. Circulation. 1971;43(5 Suppl):I77-81.

7. Miyamoto S, Hadama T, Mori Y, Shigemitsu O, Sako H, Uchida U.

Hemodynamic profiles during concurrent intraaortic balloon pumping and venoarterial bypass: a canine study comparing subclavian and femoral artery perfusion sites. Japanese circulation journal. 1995;59(10):693-703.

8. Stulak JM, Dearani JA, Burkhart HM, Barnes RD, Scott PD, Schears GJ, editors. ECMO cannulation controversies and complications. Seminars in cardiothoracic and vascular anesthesia; 2009: SAGE Publications Sage CA: Los Angeles, CA.

9. Ganslmeier P, Philipp A, Rupprecht L, Diez C, Arlt M, Mueller T, et al. Percutaneous cannulation for extracorporeal life support. The Thoracic and cardiovascular surgeon. 2011;59(02):103-7.

10. Thiele H, Zeymer U, Neumann FJ, Ferenc M, Olbrich HG, Hausleiter J, et al. Intra-aortic balloon counterpulsation in acute myocardial infarction complicated by cardiogenic shock (IABP-SHOCK II): final 12 month results of a randomised, open-label trial. Lancet. 2013;382(9905):1638-45.

11. Madershahian N, Liakopoulos OJ, Wippermann J, Salehi-Gilani S, Wittwer T, Choi YH, et al. The Impact of Intraaortic Balloon Counterpulsation on Bypass Graft Flow in Patients with Peripheral ECMO. J Cardiac Surg. 2009;24(3):265-8.

12. Belohlavek J, Mlcek M, Huptych M, Svoboda T, Havranek S, Ost'adal P, et al. Coronary versus carotid blood flow and coronary perfusion pressure in a pig model of prolonged cardiac arrest treated by different modes of venoarterial ECMO and intraaortic balloon counterpulsation. Crit Care. 2012;16(2):R50.

13. Sauren LD, Reesink KD, Selder JL, Beghi C, Van Der Veen FH, Maessen JG. The acute effect of intra□aortic balloon counterpulsation during extracorporeal life support: an experimental study. Artificial organs. 2007;31(1):31-8.

14. Kawashima D, Gojo S, Nishimura T, Itoda Y, Kitahori K, Motomura N, et al. Left ventricular mechanical support with Impella provides more ventricular unloading in heart failure than extracorporeal membrane oxygenation. ASAIO J. 2011;57(3):169-76.

15. Pappas G, Winter SD, Kopriva CJ, Steele PP. Improvement of myocardial and other vital organ functions and metabolism with a simple method of pulsatile flow (IABP) during clinical cardiopulmonary bypass. Surgery. 1975;77(1):34-44.

16. Cheng R, Hachamovitch R, Makkar R, Ramzy D, Moriguchi JD, Arabia FA, et al. Lack of Survival Benefit Found With Use of Intraaortic Balloon Pump in Extracorporeal Membrane Oxygenation: A Pooled Experience of 1517 Patients. J Invasive Cardiol. 2015;27(10):453-8.

17. Vallabhajosyula S, O'Horo JC, Antharam P, Ananthaneni S, Vallabhajosyula S, Stulak JM, et al. Concomitant Intra-Aortic Balloon Pump Use in Cardiogenic Shock Requiring Veno-Arterial Extracorporeal Membrane Oxygenation: A Systematic Review and Meta-Analysis. Circ-Cardiovasc Inte. 2018;11(9).

18. Tanaka D, Hirose H, Cavarocchi N, Entwistle JW. The impact of vascular complications on survival of patients on venoarterial extracorporeal membrane oxygenation. The Annals of thoracic surgery. 2016;101(5):1729-34.

19. Smith A, Hardison D, Bridges B, Pietsch J. Red blood cell transfusion volume and mortality among patients receiving extracorporeal membrane oxygenation. Perfusion. 2013;28(1):54-60.

20. Truby LK, Takeda K, Mauro C, Yuzefpolskaya M, Garan AR, Kirtane AJ, et al. Incidence and implications of left ventricular distention during venoarterial extracorporeal membrane oxygenation support. ASAIO Journal. 2017;63(3):257-65.

21. Hong TH, Byun JH, Lee HM, Kim YH, Kang G-H, Oh JH, et al. Initial experience of transaortic catheter venting in patients with venoarterial extracorporeal membrane oxygenation for cardiogenic shock. Asaio Journal. 2016;62(2):117-22.

22. Pappalardo F, Schulte C, Pieri M, Schrage B, Contri R, Soeffker G, et al. Concomitant implantation of Impella® on top of veno□arterial extracorporeal membrane oxygenation may improve survival of patients with cardiogenic shock. European journal of heart failure. 2017;19(3):404-12.

23. Cheng A, Swartz MF, Massey HT. Impella to unload the left ventricle during peripheral extracorporeal membrane oxygenation. Asaio Journal. 2013;59(5):533-6.

초 록

서론: 심부전 환자에게서 동정맥형 체외막형산소화장치는 매우 유용하나, 좌심실 후부하를 상승시켜 좌심실회복에 나쁜 영향을 미친다. 이에 좌심실후부하 감소를 목적으로 대동맥내 풍선장치를 추가 삽입하는 경우가 많으나, 그 효과에 대해서는 혈역학적으로 증명된 바가 없어 이를 돼지심부전 모델을 통하여 확인하고자 한다.

방법: 80kg 내외의 돼지를 이용하여 정상 심기능상태에서 대퇴동맥과 정맥을 이용하여 체외 막형 산소화장치를 삽입하고, 좌측 4번째 늑간을 통한 개흉술을 시행하여 심장을 노출한 후, 좌심방압력, 상대정맥압력측정을 시행한다. 관상동맥혈류를 대표하기 위하여 좌전하관상동맥을 노출하고, 뇌혈류를 대표하기 위하여 좌쇄골하동맥을 노출시켜 초음파 혈류를 측정한다. 1시간정도 체외막형 산소화장치를 운용을 하고 나서 대동맥풍선장치를 반대쪽 대퇴동맥에 거치하여 1시간 후에 동맥압, 좌심방압, 좌전하관상동맥혈류, 좌쇄골하동맥혈류를 측정하여 변화를 관찰한다.

심부전 모델에서는 폐동맥을 조여서 평균동맥압이 60mmHg이하로 되게 유도한 후, 체외막형 산소화 장치를 가동하고, 마찬가지로 1시간 후에 대동맥풍선장치를 거치하여 여러 가지 혈역학적 지표들의 변화를 1시간 후에 관찰한다. 정상 심기능 동물모델 4마리와 심부전 동물모델 4마리를 이용하여 지표들의 변화를 관찰하여 결과를 도출한다.

결과: 정상 심장모델에서 대동맥내 풍선장치는 평균 동맥압을 상승시키지 않았고 (118.3±25.2 체외막형 산소화 장치후 vs. 86.8±17.1mmHg 대동맥내 풍선장치 거치 후, p=0.068), 좌심방압은 감소시키는 경향을 보였으나 (9.3±7.4 vs. 3.3±2.6mmHg, p=0.068) 통계적 유의성은 보이지 않았다. 또한 관상동맥혈류나 (28.4±5.4 vs 23.6±7.7mL/min, p=0.068) 좌쇄골하동맥혈류는(161.9±55.8 vs. 123.3±45.9 mL/min, p=0.465) 대동맥내 풍선장치 후에 오히려 감소하는 경향을 보였으나 역시 통계적 유의성은 보이지 않았다. 심부전 모델에서도 대동맥풍선장치는 체외막형 산소화장치만 운용하였을때와 비교하여 평균동맥압 (93.8±20.5 vs. 89.3±19.6mmHg, p=0.716), 좌심방압의 변화나 (7.5±3.3 vs. 5.5±2.5mmHg, p=0.144) 관상동맥혈류 (9.4 vs. 21.7±3.4mL/min, p=0.197), 좌쇄골하동맥혈류 (125.6±52.4 vs. 122.3±53.4mL/min, p=1.000)의 상승을 보이지 않았다.

결론: 대동맥내 풍선장치는, 동정맥형 체외막 산소화 장치를 시행하고 있는 심부전 모델에서 혈역학적 지표에 영향을 주지 않았다..

주요어: 기계적 순환보조장치, 심부전, 체외막형 산소화장치, 대동맥내 풍선장치, 동물 실험, 심부전모델

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